FINAL

OBJECTIVE 6
An Evaluation of a Proposed Experimental Reintroduction of Sockeye Salmon into Skaha Lake:
Project Summary 2000-2003

Contribution No. *14* to an *Evaluation of an Experimental Re-introduction of Sockeye Salmon into Skaha Lake: YEAR 3 of 3*

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An Evaluation of a Proposed Experimental Reintroduction of Sockeye Salmon into Skaha Lake: Project Summary 2000-2003

by

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Prepared for the Okanagan Nation Fisheries Commission

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EXECUTIVE SUMMARY

The Okanagan stock is one of only two surviving sockeye salmon populations of the Columbia River. While the true size of its escapement in early times is not known, it may have been of considerable size in Okanagan L. and environs, but it has clearly been declining for many years (except for two good returns in 2000 and 2001) and has recently been reduced to an average annual escapement of about 20,000 fish at Wells Dam, where pre-spawners are enumerated before entering the Okanogan River.

Nine large hydroelectric dams on the Columbia R., and several smaller barrier dams on the Okanagan, along with changing environmental conditions have no doubt been instrumental in causing the population decline. McIntyre Dam below Vaseux L., British Columbia is a significant barrier as it has limited upstream migrations of sockeye since its installation in 1921 and it figures prominently in current Okanagan sockeye management decisions.

The Okanagan Nation Fisheries Commission (ONFC), and the Colville Confederated Tribes (CCT) have advocated restoration of the run to upstream areas of the basin, and with assistance from federal and provincial agencies and elsewhere, and financial support from the Bonneville Power Administration, they have undertaken investigations and coordinated inputs to evaluate possible reintroduction methods.

A major concern has been an apparent deterioration in the juvenile rearing area (now existing only in the north basin of Osoyoos Lake), and a team of investigators has concluded that development of a second, or backup rearing area is needed. Sighting on large Okanagan L. as a possible future target, they nevertheless chose the interim goal of an experimental introduction of sockeye to Skaha L., downstream from it and the third year of work to that end has now been completed

The researchers wanted a program which would not adversely affect valued resident species – particularly kokanee; one which could if necessary be discontinued without adverse effect; and one which would reveal the nature and magnitude of any risks associated with sockeye reintroduction to Okanagan L. in future.

The work has been driven by six objectives, and after three years of widely based and intensive investigation, these and interim results and conclusions are as follows:

> Obj.1: Assess the risk of disease transmission from reintroduced sockeye to resident fishes: Conclusion – at this time there is no evidence of serious risk, though recent discovery of a parasite, *Parvicapsula*, (new to the drainage) may oblige investigators to take it into account when designing reintroduction methods and monitoring.

Obj.2: Assess the risk of introducing exotic fish species to upstream waters. (i.e. above McIntyre Dam): Conclusion – Concerns are now largely limited to walleye which is at present believed to be restricted to U.S. waters.

Obj.3: Determine whether spawning and incubation areas are likely to be limiting for introduced sockeye: Conclusion – Spawning areas are sufficient for current population levels, and there is potential to increase them. New areas will almost certainly be needed in the Okanagan R. above Skaha L. eventually.

Obj 4: Develop a life cycle model: Result – A model has been developed, and found useful for a range of applications, and it has significantly improved understanding of stock dynamics and interactions with other fishes.

Obj.5: Evaluate options for an experimental reintroduction: Result – Three options have been analyzed and a first choice has been made, wherein egg takes, with hatchery incubation and fry plants would be conducted over several years.

Obj.6: Finalize a plan for an experimental reintroduction: Result - At a program review held Mar 5, 2003, most participants appeared to agree that fry plants should be the first choice, though further review may be needed as proposed implementation and monitoring plans unfold.

Research results also showed that the Osoyoos L. rearing area is currently restricted by temperature and oxygen limitations to a 3m deep vertical band of water termed a "zone of tolerance," for young sockeye. In addition the opossum shrimp *Mysis relicta*, found to be a serious competitor for food with salmonids elsewhere, may be affecting salmonid food supplies in Osoyoos, and possibly Skaha and other lakes of the Okanagan Basin. These ecological pressures may be increasing and if so they could have serious consequences for the stock.

There are no historical records of sockeye stock performance or behaviour in the upper part of the Okanagan drainage, so fish imported from the downstream components of the population will need to be monitored carefully to determine how they will respond to Skaha L. rearing conditions.

Progress to date has not revealed factors which should preclude a successful reintroduction to Skaha L. However as some questions remain unanswered, a two-track implementation program may be desirable. This would reestablish the population in Skaha and at the same time determine how widely, and with what success returning fish will again utilize the river above McIntyre Dam when it is removed or breached.

Because of the declining stock numbers and concerns about possible further habitat degradation, these initiatives should be undertaken without delay. There is a considerable body of evidence presented by independent scientists to suggest that failure to act promptly could seriously jeopardize the run. The two large escapements (2000 and 2001) could return enough fish, and provide the best opportunity for some time, to make substantial progress toward desired goals (i.e. in 2003-2005).

Participating government agencies are contributing indispensable research results, as well as participating in program planning and evaluation. It will be important to know as early as possible their availability during the next phase.

Furthermore, the fact that reproduction and early stages of Okanagan sockeye production (spawner to smolt) occur in Canada, and most of the fresh water migration (smolt to adult return) occurs in the United States underscores the importance of continuing effective across-border cooperation as the run recuperates.

Comprehensive planning is needed now to ensure both effective and efficient use of human and material resources and a number of specific actions are recommended.

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PREFACE

The purpose of this paper is to outline features of the Okanagan River sockeye salmon (*Oncorhynchus nerka*) population which have been presented at workshops or cited in Documents and Annual Reports of the Okanagan Nation Fisheries Commission, and to consider how initiatives now under way might be successfully completed. The author wishes to acknowledge the range of technical literature and original work by many investigators, some of whom may not have been cited here in the most deserving manner, and also to thank the Okanagan Nation Fisheries Commission staff and their collaborators for making these data available. To those individuals who read the draft manuscript and provided valuable comments and suggestions, many thanks.

1. INTRODUCTION

The Columbia River sockeye salmon population, of which the Okanagan stock is a part, may have numbered in excess of 4 million fish around the end of the 20th century (Fryer 1995). Since then it has been decimated by a combination of man-made and natural events such that the commercial catch, probably once well over one million fish, has been reduced to a few thousands in recent decades. Only the Okanagan stock and the Wenatchee stock in Washington State remain from the many sockeye stocks which propagated in the Columbia River Basin in early times.

2. LIFE STANZAS AND HAZARDS

The Okanagan population spawns in October, primarily in a 6 km stretch of the Okanagan River north of the town of Oliver, British Columbia (Fig 1), and about 900 km from the estuary. The vulnerable fry emerge in early spring and migrate or are carried downstream about 20km to Osoyoos Lake where they feed and grow exclusively in the northernmost lake basin until the following spring when as smolts they resume their journey south to the Columbia R. and thence to the sea. Mature fish usually return to the Columbia R. in their fourth year of age - after a little more than 24 months at sea.

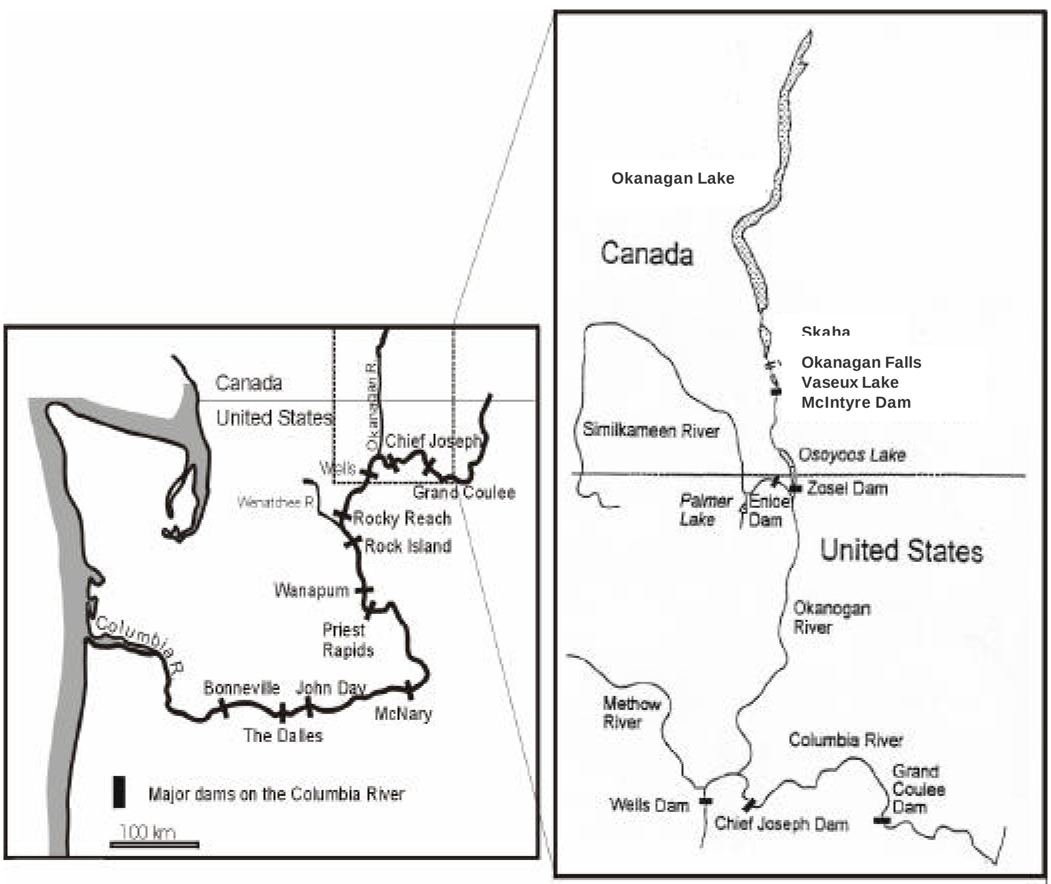

Figure 1. Columbia River and Okanagan River Drainages

Okanagan sockeye face a plethora of life threatening hazards. Returning adults proceeding upstream from the Columbia R. estuary must run the gauntlet of commercial, personal use and sport fisheries and overcome a series of 9 huge hydroelectric and water diversion dams and the reservoirs above them, even before they reach the mouth of the Okanogan R.[1] Losses have been estimated as high as 5-10% per dam (Fryer, 1995). The Wells Dam is the last the fish encounter before entering the Okanogan R, and it is the principal site of annual escapement counts. (Fig. 2 presents Wells Dam escapement data 1971-2001 as presented by Hyatt et al. MS 2002).

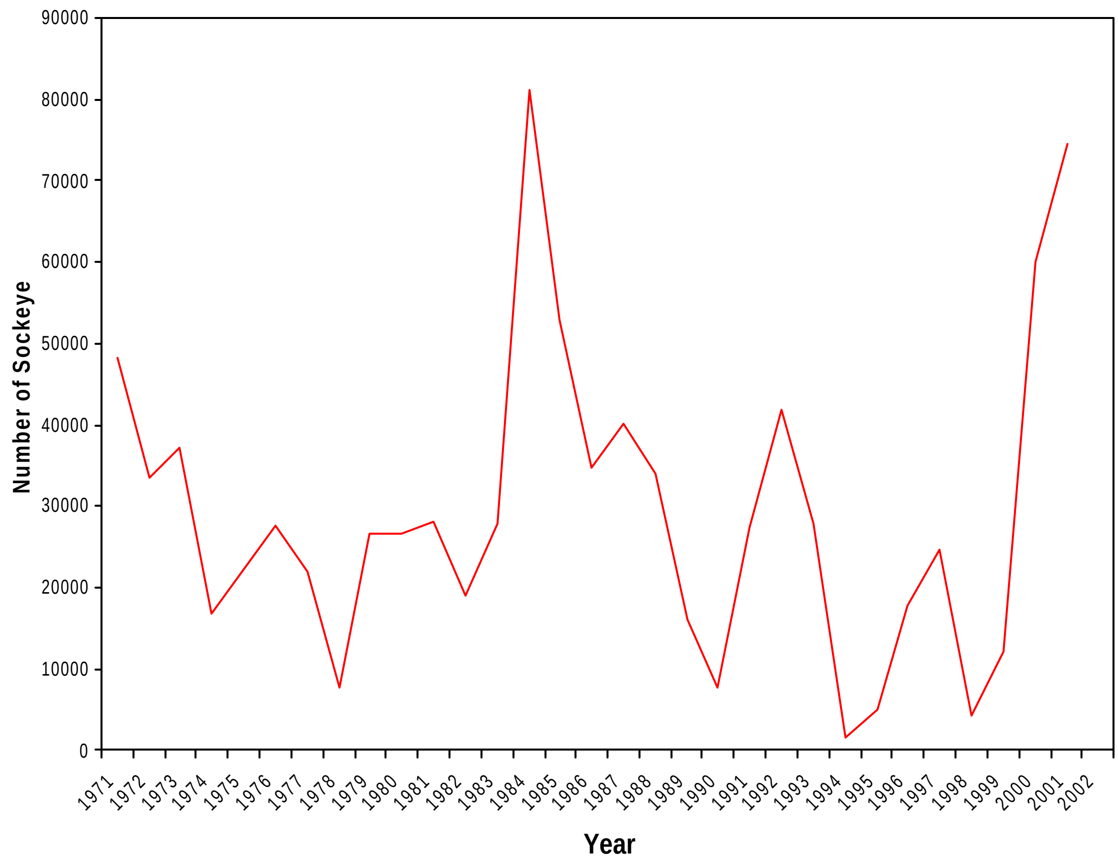

Figure 2. Counts of Okanagan sockeye salmon at Wells Dam, 1970-2001

Within the home river, agricultural needs for water, and installation of low head dams, engineered structures for flood control, diversions for irrigation, poorly screened water intakes, waste loads and the thermal and chemical changes that some of these entail, have had further significant impact on the stock. Much of the original fish habitat has gone or been radically altered and huge sections have been canalized. A water diversion and control structure – Zosel Dam - was constructed at the town of Oroville in Washington State (rebuilt in 1987), and three complete barriers to sockeye migration between Okanagan and Osoyoos lakes persist today. These are the Okanagan Lake Dam built in 1915; the Okanagan Falls, or Skaha Lake Dam (1921) and McIntyre Dam built below

[1] Okanagan R. in British Columbia is the Okanogan R. in Washington State.

Vaseux Lake also in 1921; a series of 17 vertical drop structures for flow control were added between Okanagan Falls and Osoyoos L. in the 1950s.

The burgeoning human population in the Okanagan Valley and further transformation of riparian lands can be expected to exacerbate many of these hazards. McIntyre Dam is particularly significant in that it limits further upstream migration of sockeye, thus denying access to the extensive waters above. It is a major factor in projected management decisions.

Returning adults may school at the mouth of Okanogan R. for a month or more while water temperatures cool to acceptable levels for entry and spawning. Once on the spawning grounds the salmon must find suitable beds, with rather strict requirements for gravel size and both surface and subsurface water flow and temperature, and eggs must remain well protected and safe from freezing or displacement by freshets until the young emerge. Soon thereafter the fry compete vigorously for food while constantly at risk from predators both indigenous and exotic. They are particularly susceptible to predation during their downstream migrations and during their (usually) one year of residence in the lake basin. Thereafter, as smolts, many are destroyed or injured at dams on their way seaward. Fryer (1995) considered low smolt – adult returns (commonly referred to as SARs) as the primary reason for the low population of Columbia River sockeye salmon, and characterized this daunting array of hazards to sockeye by suggesting that:

"…it is amazing that these fish manage to survive at all".

In fact 8 years after Fryers prophetic observation the stock has continued to decline except for two strong returns in 2000 and 2001. It is very difficult to forecast future run performance, but it seems probable that unless some remedial action is taken soon, the future of the stock is bleak.

Against this worrisome background the Okanagan Nation Fisheries Commission (ONFC) in Westbank, British Columbia, the Colville Confederated Tribes (CCT) in Washington State, and other groups and individuals have energetically sought restoration of the sockeye run to the Upper Okanagan R. basin, where they are believed to have flourished until the early 1900's.

While the strength of Okanagan sockeye runs, as well as those of chinook, coho, chum and possibly even pink salmon, entering the river in the early 1900's is poorly documented, newspaper articles, photographs and other publications of the time suggest that the runs not only existed, but that their combined numbers probably sustained significant native fisheries. The presence in the lakes of kokanee, sometimes termed (usually inappropriately) the "landlocked" sockeye, is further indication that the anadromous form once populated Okanagan, Skaha and likely other lakes of the upper drainage where generations of their offspring remain to the present. It is rather ironic that the kokanee, which began as a population incidental to the anadromous form, is the target of a recreational fishery in Wood and Kalamalka lakes – both tributary to Okanagan Lake - and while kokanee abundance has declined in Okanagan and Skaha lakes in recent years there was an encouraging increase again in 2002 (S. Matthews pers. comm.) and considerable sport fishing potential remains.

3. DEVELOPING A PLAN

The International Pacific Salmon Fisheries Commission established the Okanagan Basin Technical Working Group, (OBTWG) with domestic Terms of Reference (COBTWG) to be established by June, 2003 (E. Fast pers. comm.) and in 1997 a workshop comprised of their members, representatives of the ONFC and a number of invited experts was convened by the ONFC at Westbank, with discussion and proceedings facilitated by ESSA Technologies Ltd. of Vancouver, B.C. Pertinent historical data (e.g. findings of Mullan (1986), Fryer (1995) and technical information collected in ongoing investigations of the British Columbia Ministry of Water Land and Air Protection and its precursors; Fisheries and Oceans Canada, (Pacific Biological Station) and others were included in the record of the 1997 meeting and collectively these provided a strong base for further investigative planning. The Bonneville Power Administration of Portland, Oregon has provided invaluable funding for much of the work.

With a view to ultimately restoring the sockeye run to Okanagan L., workshop participants outlined areas of investigation they considered essential before the reintroduction should proceed. In particular they suggested that the critical and only rearing area in Osoyoos L. was threatened by deteriorating water quality perhaps exacerbated by climate change, and that an alternative or supplementary rearing area should be sought.

The huge Okanagan L. appeared attractive as such a rearing area. However workshop members proposed a temporizing step which was to first reintroduce fish into Skaha L., reasoning that the risks associated with a direct introduction to Okanagan L. could be substantial. In a "Skaha first" approach, much information of value to an eventual introduction to Okanagan L. could be gathered before the stock was committed to it, and given its smaller size, Skaha would probably be more amenable to a project reversal if that was necessary. In fact the proposed reintroduction was termed "An Adaptive Management Experiment", reflecting the research component and the belief that if serious difficulties arose the project could be aborted.

Required research was implicit in six program objectives. Particulars of these, and an outline of some major results after 3 years of investigations are as follows:

4. INVESTIGATIONS TOWARD A REINTRODUCTION INTO SKAHA LAKE

4.1. Objectives

Six objectives provide the framework for most of the investigations to date.[2]

1. Assess the risk of disease transmission from reintroduced sockeye to resident fishes.
2. Assess the risk of accidental introduction of exotic species to upstream waters.
3. Determine whether spawning and/or incubation areas are likely to be limiting or introduced sockeye.
4. Develop a life-cycle model.
5. Evaluate options for implementing an experimental introduction.
6. Finalize a plan for an experimental reintroduction.

(Objectives 5 and 6 are still being finalized at time of writing.)

Coordination of studies has been by the ONFC, which has also conducted much of the fieldwork and presented results in Annual Reports of 2001 and 2002. In a number of cases when background information was scant, investigators began their projects by preparing and printing extensive literature reviews, and throughout there was a demonstrated concern for the welfare of resident fish species.

4.1.1 Risk of Disease (Obj.1).

Disease experts in Provincial and Federal laboratories cooperated in the analyses of sockeye and other fish specimens collected by ONFC personnel in two river regions, i.e. above and below the McIntyre Dam barrier. Investigators tested for the presence of five potentially troublesome disease agents in several thousand specimens collected in years 2001 and 2002 and concluded:

> "There is no evidence that the fish populations above and below McIntyre Dam differ with respect to pathogens of concern. Nor is there any indication that Okanagan and Skaha lakes pose an extraordinary risk of causing disease in fish" (ONFC 2002).

This conclusion lessened concerns over the possibility of the disease spreading, but it was recommended that the barrier dam be left in place until final conclusions were reached[3].

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[2] A more detailed description can be found in Annual Reports of the ONFC,, in Peters and Marmorek (2003), and in Parnell et al (2003.)

[3] Recently, the parasite *Parvicapsula* was discovered in Okanagan sockeye from below McIntyre Dam , and while at time of writing the implications of this discovery are uncertain, if the organism does not already occur above the dam, the possibility of it spreading to there could be a serious concern.

4.1.2 Risk From Exotic fishes (Obj. 2)

It was recognized that successful reintroduction of sockeye to upstream areas could be complicated by concurrent or later upstream movement of unwanted exotic species. Initially these were thought to be: *bluegill sunfish, black crappie, largemouth bass, tench, and walleye.*

Range extension could occur when particularly McIntyre Dam, but also Okanagan Falls Dam was removed, as these species might then reach production areas above and prey on sockeye, kokanee or trout eggs or their young, or compete successfully for limited common food resources. There are a number of known predators - e.g. *smallmouth bass, rainbow trout, northern pike minnow*, already well established above McIntyre, but the concern has been largely limited to possible new arrivals.

A good understanding was needed of the likely kind and severity of hazards to valued salmonids – particularly kokanee and rainbow trout – from various exotic species. ONFC staff therefore reviewed published records of relevant interactions and habitat preferences then undertook three years of extensive riverine sampling from Okanagan L. to Osoyoos L., as well as within the lakes, utilizing six kinds of fishing gear and pre-established sites and schedules. Detailed records of catch per unit of effort (CPUE), specimen sizes and stomach analyses were taken and published in the ONFC Annual Reports along with many descriptive photographs of sampling sites and representative fish habitats (Alexis et al. 2003).

Results suggest that only walleye should still be of serious concern and then only if they should move upstream beyond their present range in the Columbia and Lower Okanogan rivers. They are known to prey on juvenile salmonids, but may not move farther upstream because of an aversion to strong light.

Studies by Williams & Brown (1982), as discussed by Vedan (ms 2003), suggest that unsuitable rearing habitat and sparse shielding from light in the Okanagan R. may be at least a partial deterrent to walleye movement there. A prominent walleye sports fisherman was consulted about the species habitat preferences, and it was concluded that if walleye reached Okanagan Valley lakes they would likely thrive and have an impact on salmon. (Alexis et al, 2003). Effort is needed to ensure that walleye do not reach Osoyoos L. Perhaps strong lighting at night would be an effective deterrent.

4.1.3 Habitat Inventory and Enhancement Opportunities (Obj. 3).

Mullan, (1986), as reported by Bull (1999) estimated the carrying capacity of the primary spawning beds north of Oliver at 35,000-50,000 fish, depending upon flows. This would be ample for escapements of the size recorded over the past 30 years. However, in view of expected demands of the reintroduced fish and extensive changes made to the river, it was deemed important to reassess the quantity, quality and carrying capacity of remaining spawning grounds, and to assess the lake rearing conditions through appropriate limnological studies.

Experienced observers provided a preliminary appraisal of the suitability of existing riverine areas and noted that there were a number of locations in channelized portions of the river where, with introduction of suitable gravels, successful spawning could be expected. In addition the area between McIntyre Dam and Okanagan L. is considered capable of supporting as many as 18,000 spawners (Bull 2001). Long (2002) has prepared a detailed inventory of potential spawning habitat in this area.

In addition preliminary engineering assessments showed that it may be feasible to improve some existing spawning beds and/or develop new ones (Newbury 2002). A "pad" of rock and gravel placed below one of the drop structures supported a number of spawning sockeye in 2002. Additional pads, placed in suitable configurations adjacent to other drop structures could be productive.

Apparently adult sockeye entering the current Skaha L. environs would have few spawning options there. Bull (2001) saw very little opportunity for lakeshore or tributary spawning, and there are no known deep water possibilities. Apparently, like the present kokanee population, sockeye rearing in Skaha L. and returning as adults will need to spawn in the river, and almost certainly above, rather than below the lake. Inspection and measurement of the canalized river channel and flow conditions there showed that several spawning beds could be developed with space for about 4,000 pairs of sockeye and 3,700 pairs of kokanee (Long & Newbury 2002). In summary it appears that existing Okanagan River spawning areas could be significantly augmented if required and it is likely that such action will eventually be needed to provide for returning Skaha L. fish.

4.1.3.1 Limnology and the Osoyoos Lake Zone of Tolerance

Limnological investigations on larger Okanagan Valley lakes have been carried out by both federal and provincial agencies for many years, and a considerable body of relevant and valuable information exists. Building on this, and in concert with ongoing agency work, ONFC studies have largely been concentrated at established stations on Skaha, Osoyoos, Vaseux and Okanagan lakes to collect physical, chemical and biological data bearing upon carrying capacity for sockeye juveniles, and conditions in holding and resting areas where adults wait for river temperatures to decline.

Data presented by Wright & Lawrence (2003) show a juvenile rearing capacity in Skaha L. equal to about 80-90% of that currently found in Osoyoos L and when "zones of tolerance" were plotted (areas where maximum seasonal water temperatures and minimum oxygen levels are tolerable for young sockeye -- P. Rankin to H. Wright, pers. comm.), it appeared that juveniles would not likely have been restricted by those factors in Skaha L. in either 2001 or 2002. On the other hand in Osoyoos L. only the north basin (water mass north of Osoyoos, B.C.) had suitable rearing area in August and September, and in September that was restricted to a narrow horizontal band only about 2 – 3 m. deep. This area will require a close watch in order to detect any further reduction in carrying capacity. It could be very helpful if relevant conditions prior to 2001 could also be determined.

Three km. long Vaseux Lake, with a maximum depth of about 28m lies on the migration path and would pose a serious hazard for any sockeye juveniles attempting to migrate through it between July and September when intolerably high temperatures and low dissolved oxygen levels prevail. It is thought not to have any year-round rearing habitat suitable for sockeye juveniles (Wright 2002) and it supports a large population of rough fishes, including species predatory on salmonids.

4.1.3.2 Mysis relicta

The ½inch long opossum shr imp, Mysis relicta is now ubiquitous in most of the larger Okanagan Valley lakes. Introduced to Okanagan L. in 1966 as a food source for kokanee, it has expanded its range, and because its own planktonic food preferences mirror those of young salmonids, it may affect food availability for the latter in Osoyoos and Skaha lakes and elsewhere. Mysis has been introduced into other kokanee bearing lakes, and may have been the cause of fish reductions there. Because food supplies of sockeye juveniles in Osoyoos L. and kokanee in Skaha L. could be threatened by further proliferation of mysis, concerted sampling and research continues. A small commercial fishery for mysis exists on Okanagan L.

4.1.4 Develop a Life Cycle Model (Obj. 4)

Salmon stock performance is influenced by a great number of variables in each of river, lake and ocean environments and this makes forecasting abundance and behaviour very difficult to achieve. For instance, smolt to adult survival rates (SAR) among Okanagan sockeye are estimated to have varied from 0.6% to 6.6% in the few years for which there are data within the period 1965 - 1976 (Mullan 1986), cited in Fryer (1995). (Okanagan River sockeye data sets are notoriously incomplete.) However modeling can often be a useful tool for exploring variability and suggesting how stock dynamics may unfold.

ESSA Technologies developed a life cycle model for Okanagan sockeye and, interacting closely with workshop participants over several years, they completed a number of very informative analyses. The model considers factors affecting survival at each life history stage, and allows users to easily modify both human management actions and to hypothesize functional relationships, as described in the Design Document (Peters and Marmorek 2003) and Users Guide (Pinkham and Peters 2003). Details of the applications of the model can be found in Parnell et al. (2003).

4.1.4.1 Modeling of Reintroduction Options

ESSA scientists demonstrated model effectiveness by reproducing the observed geometric mean abundance of Okanagan adult sockeye (about 20,000 at Wells Dam counting station over a 25-year period) but – significantly – to achieve this, the mean SAR[4] had to be increased to 2.65 %, well above recent observed average values of about 1.0%. Nevertheless this successful escapement size simulation lends confidence that the

[4] SAR here refers to the survival of fish from smolts leaving Wells Dam to adults returning to Bonneville Dam (ESSA, pers.comm)

model can reflect reality and in this instance it also suggests the importance of the SAR as a determinant of run success.
In one series of analyses, the 3 reintroduction methods discussed on p.9 were modeled and results supported the view that reintroduction option No. 3, wherein fry would be released to the lake, would best satisfy the specified criteria. In options 1 and 2 the need to take larger numbers of spawners affected the stock unfavourably.[5]

This analysis also showed that introductions of 200 sockeye fry/ha should have relatively little effect on overall sockeye adult and fry performance, as well as on numbers of kokanee, and density of mysids, though in common with several other analyses in the modeling series, stock strength was seen to decline rapidly in the final few assessment years. This analysis was repeated, with removal of 50% of the mysis population each year and in this run both kokanee and sockeye fry numbers increased Apparently removal of part of the mysis population could benefit both kokanee and salmon populations.

4.1.4.2 Effect of fry density

When sockeye fry were introduced to give, successively densities of 200, 800, and 1000 fry/ha the survival rates of each of sockeye, kokanee and mysids remained unchanged. However the species specific survival rates at all three levels of introduction suggested that:

1. Kokanee are sensitive to mysis but not sockeye.
2. Sockeye are sensitive to kokanee, but more sensitive to mysis.
3. Mysis are insensitive to both sockeye and kokanee.

This analysis suggests that introducing sockeye fry in Skaha L. at concentrations as high as 1000 fry per hectare should not be a problem for kokanee, and it reinforces the view that mysis is apt to be a troublesome creature for both kokanee and sockeye.

4.1.4.3 Kokanee increases

Workshop attendees wished to know what conditions would likely increase the long-term average Skaha kokanee spawner population from the current 7,950, to the levels observed in the late 1960's of about 80,000 fish. The model suggested that removing competition (from mysis), doubling egg-fry survival, and tripling the amount of spawning habitat, could accomplish that end. (This is not to say that other combinations of change would not be capable of a similar result, but it does suggest that considerable effort might be required to sustain a population of 80,000 spawners under present conditions of stock and habitat).

[5] Under option one, 385 spawners would be required for an introduction of 200 fry/ha, given normal fertilization and hatchery survival rates, whereas 3,454 would be required under option 2. (Some reduction in numbers might be achieved by reducing the number of males needed for fertilization)

4.1.4.4 Other preliminary conclusions

The following items drawn from the modeling exercise are also important:

a) When mysis density in Osoyoos Lake was increased from 6m3/ha, to130m3/ha – the latter being the simulated density in Osoyoos Lake at the end of 25 years, -sockeye spawners were reduced from 20,000 to 6,000 fish.
b) In the absence of mysis Skaha L. kokanee appear to have an equilibrium spawning population (wherein natural variability is removed from the equation) of about 23,000, but with mysis present only 1500.

These results once again suggest that mysis has the potential to diminish salmonid production. It should be noted however, that because mysis is also a food item for larger kokanee there may be tradeoffs, featuring both positive, and negative effects on the population. The interaction dynamics are likely quite complex and deserve further research.

The model was also used for initial evaluations of the ability to detect impacts on kokanee of different types of sockeye re-introduction experiments (e.g. a 5-year baseline period followed by a 5-year re-introduction period). Preliminary analyses indicated that because the apparent effects of sockeye re-introduction on kokanee survival were so small in magnitude, they would be almost impossible to detect. Larger changes in kokanee fry to age 0 survival (e.g. a 40% change in survival either up or down) could likely be detected at an acceptable level of statistical power. More comprehensive work on statistical analyses and experimental design could be instructive (see pg. 69 of Parnell et al. 2003).

4.1.5 Methods of Reintroduction

Sockeye workshop participants considered three viable options for reintroducing sockeye into Skaha L., and put forward criteria which could be used to prioritize them:

4.1.5.1 Options

1. Remove barriers (McIntyre and Okanagan Falls dams) to migration between Osoyoos and Skaha lakes – thus allowing migrants to move into Skaha unimpeded.
2. Trap migrants (probably below McIntyre Dam), transport to Skaha and release allowing them to find their own spawning areas.
3. Trap migrants, extract and fertilize eggs, incubate in a local (and disease free) hatchery and release fry into Skaha.

4.1.5.2 Criteria for Success

It was thought that a successful reintroduction process should:

a) provide a satisfactory level of learning
b) conserve existing stocks of both sockeye, and kokanee; and
c) eventually produce a population with a large enough surplus to once again support a substantial fishery, notably for ceremonial purposes.

Option three was thought to best satisfy the three criteria, all things considered. It was particularly strong from a learning perspective; it would enable precisely the required numbers of fry to be introduced into the lake; and by marking the fry investigators could accurately measure their survival to later life stages. Option 3 also has conservation value in that a comparatively small number of pre-spawners would need to be sacrificed, and any possible deleterious interaction, (e.g. strong competition between returning sockeye and resident kokanee for spawning space) would be avoided -- at least during years when sockeye adults were prevented from entering the upper river. Finally it should be a relatively dependable, and speedy way of generating data on Skaha L. rearing effectiveness provided abundance of kokanee and sockeye juveniles are carefully monitored. In the other methods, wherein fish would need to find their own spawning grounds in or above Skaha L., their spawning and incubation success would be unpredictable and very difficult to measure, and uncertain escapement strength or upstream travel distance could preclude a satisfactory spawning in or near Skaha L.

In reintroduction options one and two, there would also be doubt as to how fish produced in Skaha L. would be distributed at return, as they would not be distinguishable from spawners that reared in Osoyoos Lake. In any choice of reintroduction, wherein barriers remained to prevent complete homing, the fish would most likely spawn with the main population near McIntyre Dam. That could result in an unwanted level of competition both on the spawning grounds and later in the Osoyoos L. rearing area. This concern could of course apply in any year of exceptionally high abundance with or without enhanced production.

While option three is particularly attractive from the important standpoint of quickly achieving the desired Skaha L. population level, there is nevertheless a body of resistance to any “non-natural” reintroduction process. It may be argued that if given the opportunity (i.e. removing or broaching barriers) the fish will find their own way, select productive spawning sites and thereby obviate the need for hatchery rearing with all the uncertainty that implies. Some workshop participants thought that because each method has its own risks and benefits, it may be desirable to implement each of these sequentially or concurrently in an experimental framework. Further review may be needed before a final decision is made.

Some parts of the run may be more successful than others if used as donor stock for the reintroduction. A number of fish usually arrive at McIntyre Dam ahead of the main run each season, attempt to get through the dam, then fall back and presumably spawn somewhere below it. If, as seems credible, these fish are remnants of an early run component seeking access to historical spawning grounds – perhaps in Okanagan L.- they may be genetically the best suited as brood stock for Skaha. In any event both the run and the dam can be managed to utilize fish from any desired part of the run. However, one should anticipate that due to temperature-induced migration delays in the Okanogan River above Wells Dam or for other reasons, in many years there may be very few or no 'early run' spawners.

Workshop planners thought that a number of "pre-experiment" years would be needed to develop reliable baseline data, and given the likely variability in year-to-year fry survival, additional time would be required before accumulated production data could be accepted with confidence. Furthermore some minimum number of fish would have to arrive at McIntyre Dam before investigators were satisfied that the required numbers could be safely removed for the egg take. Based upon past run performance there could very well be years when no removal could be permitted, thus necessitating further extension to the period of experimental reintroduction. The total numbers of years required and the minimum acceptable escapement size are still to be finalized but may prove to be a critical burden in achieving a speedy reintroduction.

5. SYNTHESIS OF RESULTS AND SOME SUGGESTIONS FOR THE FUTURE

Progress toward meeting the six program objectives has been effective and has not revealed factors which should preclude a successful reintroduction to Skaha Lake:

1. Serious disease transfer between waters above, and waters below McIntyre Dam seems unlikely, unless recently discovered *Parvicapsula* becomes a problem.
2. Concerns over exotic fish introductions can now be centred on walleye though that species has not been recorded from upstream of the International Boundary. In view of its potential for damage to salmonids every effort should be made to keep it out of Osoyoos L.
3. Spawning areas appear adequate for present population levels, and there is potential to increase them to accommodate Skaha L., or other new production.
4. A life cycle model has been developed and tested and shown to be promising as a tool for improving understanding of run dynamics, exploring intraspecific competition, and assessing the relative benefits and risks of alternative reintroduction, mitigation and monitoring strategies. Several options for an experimental introduction of sockeye to Skaha L. have been evaluated, and prioritized. In balance a fry introduction seems the best approach, though it may deserve further exploration.
5. Planning for the reintroduction is progressing and with secure funding some preparatory work could probably get under way quite quickly.

These are substantial and encouraging accomplishments, and they provide a strong rationale for recommending reintroduction of sockeye salmon to Skaha L. At the same time some significant concerns persist and these will need to be explored farther as work progresses.

For instance the persistent stock decline is worrisome: In 30 years of data from Wells Dam (data courtesy of Hyatt et al. 2001) the sum of 15 consecutive escapements, from 1971 – 1986, were 1.3 times the sum of the following 15 consecutive escapements from 1987 – 2001. Peters et al (1998) suggested that without some form of intervention to improve survival rates the stock could go to extinction. A competent biometrician might be able to extrapolate from available data to cast further light on the likely outcome.

Concern over low smolt to adult survival is also pervasive, and if it cannot improved, for instance by affording greater protection at dams, a larger number of juveniles may be required to bolster the stock. Reductions in commercial, and other Lower Columbia River fisheries may be needed, both as a means of getting more fish onto the spawning grounds and (incidentally) in the long term interests of the fishermen themselves. Moreover, the very limited layer of Osoyoos L. waters which at present seems capable of supporting juveniles in the summer months could become further restricted, and under extreme circumstances might disappear entirely, with disastrous consequences for the fish. Finally the burgeoning mysis population seems a serious threat to both anadromous sockeye and kokanee and the existing mysis fishery may deserve expansion.

In view of these concerns there is a need to move quickly to a Skaha L. reintroduction as well as to extend data sets which will be needed to more completely assess sockeye interactions with resident fishes and the environment. No stock assessment data exists for sockeye using waters above McIntyre Dam, so their perceived reproductive success and behaviour there must be considered somewhat conjectural.

Though it is not a concern while the barrier dams are intact, the shortage of spawning area in Skaha and its tributary streams will oblige the fish to spawn in the river, either below or above the lake. The channelized section of river below Okanagan L. is where considerable kokanee spawning occurs now, but at present there is insufficient graveled area to additionally support the expected anadromous population. As noted previously, more spawning area will have to be created before adults return.

The workshop recommendation to reintroduce sockeye to Skaha Lake first, rather than directly to Okanagan L. appears to have been a sensible one despite some substantial physical and biological differences in the two lakes, which could make the Skaha experiment less than a perfect model for Okanagan. Nevertheless progress has been made on a number of critical questions about run dynamics and species interactions which could apply equally well to populations in either lake. A great deal of valuable information has been assembled from the three years of study and the rigorous approach to the work exhibited by participants should give comfort to those contemplating the next steps.

5.1. Behavioural Issues

There are some uncertainties about how fry reintroduced to Skaha L. from the downstream segment of the population will behave and these will need to be resolved as quickly as possible. For instance, depending upon where in the lake they are released, fry may move toward the outlet, and some might then choose to enter, or be carried by the current into the river. After all, the fry stage of the parent stock was apparently genetically programmed to move downstream to the Osoyoos L. nursery area and presumably their progeny will carry the same predisposition. A release well away from the lake outlet and away from any discernible southerly current would seem prudent, as would subsequent monitoring at the Okanagan Falls Dam to enable any exodus to be measured.

It is not unusual for sockeye population units in the same river system to have different responses to flow and substrate and Brannon (1972) reporting on fry behaviour in several Fraser River stocks concluded that: "…mechanics controlling sockeye fry migration are genetically based, and involve racially specific velocity response patterns..."

It is also important that the fish move directly seaward as smolts. While a significant number might reach Osoyoos L. as fry and become integrated with the down river fish this would largely defeat the aim of establishing a back-up rearing area in Skaha L., and in a year of high production and/or lowered carrying capacity in Osoyoos L. it could pose an untenable burden on the rearing area. Furthermore the 30 km downstream trip as fry could be very hazardous, perhaps intolerable, particularly in view of the inhospitable conditions expected to occur in Vaseux L. A migration at smolt size should impart significant survival advantage, and intuitively one would expect migration to occur at that stage but in the absence of relevant upstream sockeye stock data the outcome is hardly assured.

It is also possible that introduced juveniles, perhaps influenced by food availability and different growth rates to those experienced in Osoyoos L, could find the Skaha environment conducive to a longer period of residence, and in a further departure from expected behaviour, part of the population might remain and become mixed with the kokanee population. These possibilities seem rather unlikely but should be watched for. Such behaviour might be more likely to occur in a larger water body such as Okanagan L.

It should also be remembered that the Okanagan River has been drastically modified since times of past larger runs. Sockeye behaviour geared to conditions extant then, may not serve quite so well in today's environment. One cannot help wondering if Skaha L. could simply have been a conduit for salmon passing to and from Okanagan L., without there being much in the way of local spawning opportunity, but with a lake basin able to support a kokanee population originating in more attractive Okanagan Lake spawning grounds?

Investigators also need to learn as soon as possible how adult spawners will distribute themselves in the river between McIntyre and Okanagan Falls; how effective their spawning there will be; and how serious a problem Vaseux Lake will be for juveniles passing through it. Unless the fry introduction is to continue indefinitely managers will have to face these issues eventually and as time is surely an issue, this river work should be carried on at the same time as the fry experiments in a kind of "two track" approach. The central question is: What combination of number of spawners, river discharge and temperature will result in fish reaching the Okanagan Falls barrier dam as opposed to spawning farther downstream?

5.2. Need for a Two-Track Approach.

In such a two-track approach McIntyre dam would remain in place as recommended for reintroduction option three discussed above, but modified to allow a controlled number of fish to enter the upper river perhaps via a narrow fish ladder, or a side channel as illustrated by Newbury (2001, Figs 4.8 & 4.9). A decision on numbers would be subject to the same kind of critical examination proposed for the fry introduction. Knowledge of the productivity of this stretch of river will be needed to manage stock distribution over the long term. While Skaha L. adults can be expected to home on the nursery lake, a fraction of the population will no doubt always remain in the river.

As noted in the modeling workshop, there is no assurance that escapement numbers in any given year will be sufficiently large to permit removal of adults for the fry introduction, so a further removal of spawners for the river studies would be a substantial additional burden when returns are weak. Given the large escapements in 2000 and 2001, the next two or three years (2003 – 2005) may, with reasonably good smolt, marine and adult migration survivals, provide the largest surplus to be seen for some time and considerable effort would be justified to ensure capitalizing on such a "window of opportunity". Timely information from Wells Dam on escapement size can provide advance warning about numbers of fish likely to be available on the spawning grounds and allow field crews to plan accordingly.

These issues will need to be closely monitored in order to obtain prompt warning of any further stock decline or alteration of habitat. Climate change, which could also affect the runs is largely beyond control but needs watching if effects are to be anticipated.

5.3. Agency Participation.

The agencies now participating in the reintroduction project are providing vital expertise and information, and it will be important to know, as early and as fully as possible, the nature of their contributions to the next phase. While reproduction and the early stages of Okanagan sockeye production capacity (spawner to smolt) occurs in Canada, most of the fresh water migration (smolt to adult return) occurs in the United States. Clearly agencies of both countries will need to be involved to ensure that rearing facilities are sufficient and protected, and that commercial, personal use and sport fisheries are well regulated as the run recuperates. Initiatives to improve adult and juvenile passage through the Columbia River dams should continue, and it will be helpful to know their nature and degree of success.

Reconstitution of past stock performance using the best information available, and maintaining up to date records will be of great importance to investigators seeking improved understanding of run dynamics and a solid information base on which to build future initiatives.

As a final note attention should be directed to the workshop participants concern over finding the right balance between too slow action which could result in loss of the stock (the conservation issue) and too precipitous action leading to bad decisions (the production issue). One cannot foresee with any degree of assurance how many years the run can persist unaided. It is clear however that unless the run is kept reasonably robust there will be few options for intervention of any kind. A cautious and thoughtful lean toward conservation appears justified to ensure that this highly valued resource survives.

6. RECOMMENDATIONS

Comprehensive planning should accelerate to ensure both effective and efficient use of human and material resources. The following steps are suggested:

1. Take eggs from adults of the 2003 escapement, incubate for release into Skaha L. in 2004, and establish a sampling facility at the lake outlet.
2. Adjust McIntyre Dam gates to enable a controlled adult sockeye access to the river above.
3. Continue evaluation of Osoyoos L. “Zone of Tolerance” for juvenile sockeye, and if possible delineate boundaries prevailing prior to 2001.
4. Continue mysis studies to clearly reveal population trends at least in Osoyoos, Skaha and Okanagan lakes.
5. Develop a study specifically to describe sockeye-kokanee-mysis interactions and food regimens.
6. Install spawning pads in the river below Okanagan L as described by Long & Newbury (2002).
7. Review sockeye stock information and arrange for timely acquisition of data needed seasonally: e.g. escapement at Wells Dam, catch from all sources, numbers of river spawners, smolts at Zosel Dam etc.
8. Continue surveillance to assess walleye distribution and explore means of keeping them out of Osoyoos Lake.
9. Develop detailed 5-yr or similar length plan for reintroduction steps: e.g. rules to govern required escapement size before egg takes occur; sampling required to assess fry reintroduction success, etc.
10. Develop a monitoring program for critical data acquisitions

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